





Spatio-temporal variation in the density and diversity of decapods captured with artisanal traps in an Amazon estuary

Variação espaço-temporal na densidade e diversidade de decápodes capturados com armadilhas artesanais em um estuário amazônico

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Abstract: Aim: The variability in density and species diversity of decapod crustaceans was investigated on four islands with different degrees of anthropogenic disturbance around the city of Belém, State of Pará. **Methods:** Samples were obtained from 15 creeks using artisanal traps, every three months between October 2013 and May 2014 on Combu, Onças, Cotijuba and Mosqueiro islands. **Results:** Salinity and temperature little varied, which is common for a tropical Amazon estuary strongly influenced by freshwater inflow. A total of 8,367 decapods were captured, with one record of an exotic species *Penaeus monodon*. In all seasons, decapod density and richness tended to increase from Combu to Mosqueiro, with increasing proximity to the sea and higher salinity and pH. Except for Combu, species richness and Margalef diversity tended to be slightly greater in the wet season at all islands, especially Onças. Evenness and Shannon diversity did not vary greatly between seasons but were lowest at Onças in the dry season and highest at Combu, decreasing to Mosqueiro, in the wet season. In general, ecological indices are similar in the dry and transition dry to wet seasons, and in the wet season, dominance occurs at Mosqueiro Island. *Macrobrachium acanthurus*, *C. bocourti* and *P. gracillis* were associated with the wet season, whereas *M. surinamicum* prefers the dry season. *M. amazonicum* and *Macrobrachium* sp. have no well-defined seasonal pattern of occurrence at all the islands. **Conclusions:** Despite anthropogenic disturbances and proximity to large human populations, especially on Mosqueiro Island, the density and diversity of decapod crustaceans appear to be reasonably unaffected for the moment.

Keywords: Northern coast of Brazil; *Macrobrachium amazonicum*; Decapod, ecological index.



Resumo: Objetivo: A variabilidade na densidade e diversidade de espécies de crustáceos decápodes foi investigada em quatro ilhas com diferentes graus de perturbação antropogênica em torno da cidade de Belém, Estado do Pará. **Métodos:** Foram obtidas amostras de 15 canais de maré utilizando armadilhas artesanais, a cada três meses, entre outubro de 2013 e maio de 2014 nas ilhas Combu, Onças, Cotijuba e Mosqueiro. **Resultados:** A salinidade e a temperatura variaram pouco, o que é comum em um estuário amazônico tropical fortemente influenciado pelo influxo de água doce. Foram capturados um total de 8.367 decápodes, com um registro de uma espécie exótica, *Penaeus monodon*. Em todas as estações, a densidade e riqueza de decápodes aumentou de Combu para Mosqueiro, com a crescente proximidade do mar e maior salinidade e pH. Com exceção de Combu, a riqueza de espécies e diversidade de Margalef tendeu a ser ligeiramente maior na estação chuvosa em todas as ilhas, especialmente em Onças. A Equitabilidade e a diversidade de Shannon foram semelhantes entre as estações, mas eram mais baixas em Onças na estação seca e mais alta em Combu, diminuindo para Mosqueiro na estação chuvosa. Em geral, os índices ecológicos são semelhantes na estação seca e na transição da seca para a estação chuvosa, na estação chuvosa a dominância ocorre na Ilha de Mosqueiro. *M. acanthurus*, *C. bocourti* e *P. gracilllis* foram associadas à estação das chuvas, enquanto que *M. surinamicum* prefere a estação seca. *M. amazonicum* e *Macrobrachium* sp. não têm um padrão de ocorrência sazonal definido em todas as ilhas. **Conclusões:** Apesar das perturbações antropogênicas e da proximidade a grandes populações humanas, especialmente na Ilha do Mosqueiro, a densidade e diversidade de crustáceos decápodes parecem ser razoavelmente não afetadas no momento.

Palavras-chave: Costa Norte do Brasil; *Macrobrachium amazonicum*; Decápodes; índices ecológicos.

1. Introduction

Decapod crustaceans have been widely studied on the Amazon coast (Bentes et al., 2011, Vergamini et al., 2011, Pantaleão et al., 2012, Oliveira et al., 2013; Amaral et al., 2014; Lima et al., 2014; de Oliveira et al., 2016; Freire et al., 2017) where they are extensively exploited by artisanal fisheries for subsistence and commercial purposes (Bentes et al., 2011). As an example, *Macrobrachium amazonicum* populations invariably present signs of overfishing (Freire et al., 2012), and are not self-renewing adequately due to the capture of immature shrimp, thus making their fishing unsustainable (Lucena-Frédou et al., 2010).

The decapod genus *Macrobrachium* includes approximately 240 species (Wowor et al., 2009; De Grave & Fransen, 2011), and is found in tropical and subtropical fresh and brackish waters worldwide (Pereira et al., 2002; Short, 2004), as a result of its highly adaptive reproductive and life history strategy (Short, 2004; Pileggi & Mantelatto, 2010). In South America, the genus has a wide distribution in the basins of the Orinoco, Amazonas and Paraguay rivers, being abundant in waters rich in sediment and dissolved salts in the central Amazon River basin (Odinetz-Collart & Moreira, 1993). In Brazil, there are 17 species of the genus (Pileggi & Mantelatto, 2012).

Shrimp and crabs inhabit marine, coastal and estuarine waters (Magalhães, 2003) and are important for connectivity among different trophic levels of the food web (Barros & Pimentel 2001; Albertoni et al., 2003a; 2003b). With relatively short life cycles

and high sensitivity to environmental pollutants, decapods are considered useful indicators of water quality (Rinderhagen et al., 2000; Pârvulescu et al., 2011; Kuklina et al., 2013) as they respond rapidly to both natural and anthropogenic environmental impacts (Füreder & Reynolds 2003; Alcorlo et al., 2006; Rak et al., 2011).

Environmental, habitat and other factors, such as currents, temperature, salinity, nutrients, light, food availability and length of the larval life cycle influence the spatial and seasonal distribution of many decapods, and may also interfere in the composition, abundance and diversity of species, especially during the larval planktonic phase (Anger, 2001; Koettker & Freire, 2006; Landeira et al., 2010). Estuarine zones, located at the interface between river and sea, undergo wide spatial and seasonal variability in environmental conditions due to the influences of both continental riverine input and coastal waters (Bald et al., 2005).

Anthropogenic disturbances affect water quality and consequently aquatic biodiversity, and may interfere with trophic structure, spatio-temporal distribution of individuals and cause a decrease in species diversity (Eddy, 2005; Vieira & Shibatta, 2007). Located to the west of Belém city (State capital of Pará, Brazil), and extending to Mosqueiro Island, Guajará Bay is formed by the convergence of the Guamá and Acará rivers. A group of islands and channels/creeks characterize the left bank of Guajará Bay. This region suffers from the effects of urban influences from Belém, such as the release of untreated sewage waste, fish processing industries

and petrochemical residues, which are released directly into the Guajará Bay (Ribeiro, 2004; Viana et al., 2010; Wanderley, 2010).

The island of Mosqueiro is the largest, most urbanized and populous island around the city of Belém, with around 30 thousand inhabitants (IBGE, 2010), has access both by river and by road and has a fishing port that supplies the markets of Belém and receives an intense flow of tourists to its 24 beaches (Ribeiro et al., 2013). On the contrary, the smaller islands, Combu, Onças, and Cotijuba have little or no urbanization and are characterized by small, scattered riverine populations, which mainly carry out harvesting of fruit and small-scale artisanal fishing (Ribeiro, 2004). In this context, the present study investigates how the spatio-temporal variation, abundance and diversity of decapod crustaceans are structured in relation to human activities in Guajará Bay and Mosqueiro Island, in the eastern Brazilian Amazon.

2. Material and Methods

2.1. Study area and sampling

Guajará Bay is formed by an island complex (Combu, Onças, and Cotijuba Islands) in the

southern arm of the Amazon estuary, and further north is Mosqueiro Island, the largest of the four islands, which together, form a unique and dynamic aquatic environment characterized by high levels of fluvial and tidal energy and large amounts of suspended material (Dillenburg & Hesp, 2008; Souza-Filho et al., 2011; Rosa-Filho et al., 2018), limiting the penetration of sunlight (Smith, 2002; Gregório & Mendes, 2011). Semi-diurnal macrotides (up to 6 m in Pará) (DHN, 2010) flood channel banks in the region; significant saltwater entry only occurs during the driest months (July-December), when precipitation and river discharge are lower (Souza-Filho et al., 2011; Rosa-Filho et al., 2018).

Decapod sampling took place every three months between October 2013 and May 2014 at differing numbers of sites on three islands around Guajará Bay; Combu (n=2), Onças (n=4), and Cotijuba (n=2) and Mosqueiro Island (n=7) (Figure 1). To standardize the sampling locations, the number of creeks per island was decided as a function of the area of the respective island (km²). Sampling periods were categorized according to the prevailing season: Dry (October to November),

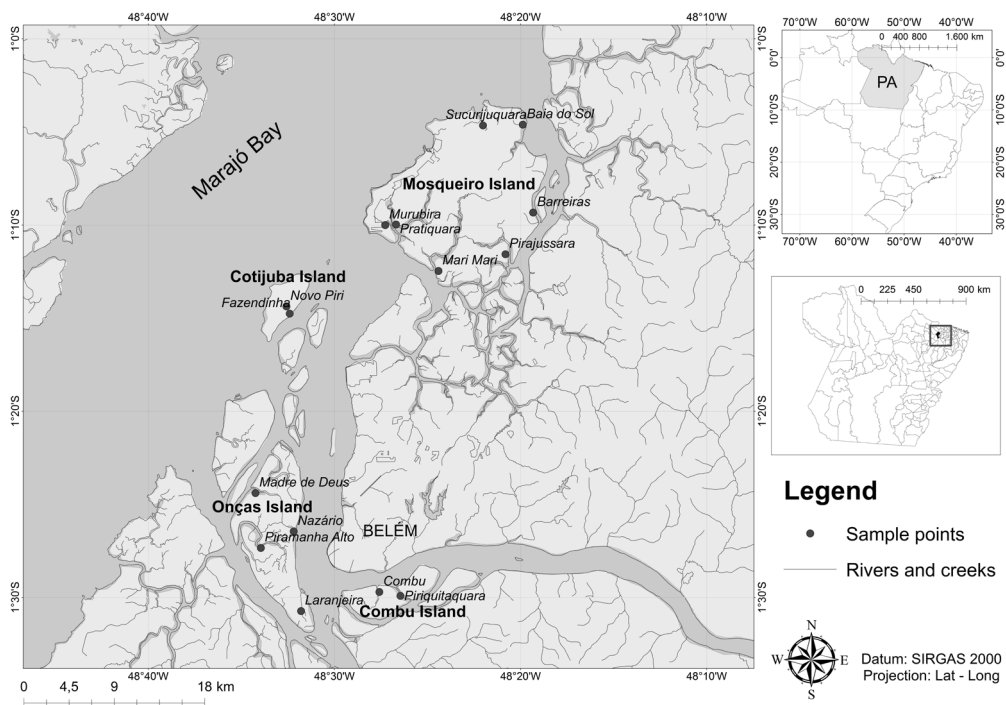


Figure 1. Sites at Combu Island (Combu, Piriquitaquara), Onças Island (Madre de Deus, Nazário, Piramanha Alto, Laranjeira), Cotijuba Island (Fazendinha, Novo Piri) in Guajará Bay and Mosqueiro Island (Baía do Sol, Barreiras, Mari Mari, Murubira, Pirajussara, Pratiquera, Sucurijuquara) sampled for decapod crustaceans between October 2013 and May 2014.

Transition Dry to Wet or TDW (December to January), and Wet (February to May).

Specimens were collected with artisanal traps, known locally as *matapis* (Figure 2), which are made from thin rods of palm fronds (*Astrocaryum* spp. and *Atrix* spp.), baited with *babaçu* (*Orbignya speciosa*) flour. Five *matapis* were used at each site, arranged equidistant along a local stream, between its mouth and source. The traps were set two days before the new moon, on the last low tide of the day. On the first low tide of the following day (12 hours later), the traps were retrieved (Freire et al., 2012). Due to sampling problems, data for Onças Island are not available for the transition period from dry to rainy (TDW).

Specimens of shrimps and crabs collected in the traps were identified to the lowest possible taxonomic level. Salinity, temperature (°C), dissolved oxygen (% saturation), and pH were measured with a Hanna HI 9828 digital meter at both deployment and removal of traps, from which a mean value was calculated.

2.2. Data analysis

Density (N) was the sum per island of the individuals collected in the five *matapis* in each stream channel (site) in each season. Since the number of streams channel per island was decided based on their respective area, the total number of *matapis* per island was different at each station. Due to interference or loss of sampling units, faunal replicates were absent or low in certain seasons at some islands, and thus no attempt was made to carry out a statistical analysis on the ecological indices data. For each decapod sample, species richness was determined, and the Margalef (D), equitability (J') and Shannon diversity (H') indices were calculated in the *Diverse* routine in PRIMER 6.0. These ecological indices were chosen because they are commonly used in studies with abundance of decapod crustacean, responding in a robust way to the comparison of the fauna among the islands.

To check if decapod species richness was adequately sampled, species accumulation curves were generated for cumulative sampling effort on each island and the total cumulative sampling effort using the jackknife1 estimator, with sites added in random order, using the *specaccum()* function in the *vegan* package (Oksanen et al., 2020) in GNU R 4.0.4 (R Core Team, 2021).

Ordination by canonical analysis of principal coordinates (CAP, Anderson & Willis, 2003) using the *capscale()* function in the *vegan* package (Oksanen et al., 2020) on a Bray–Curtis dissimilarity matrix calculated from decapod crustacean species presence and absence data, was used to verify differences in species occurrence and composition among islands and seasons, as well as determine the degree of association with abiotic factors, also using the *envfit()* function in the *vegan* package.

Differences in the multivariate pattern of variation in environmental variables were formally checked using permutational multivariate analysis of variance (PERMANOVA) with the *adonis()* function in the *vegan* package (Oksanen et al., 2020).

3. Results

3.1. Abiotic data

In the dry season, salinity varied between 0.01 and 1.78 among sites, being higher at Cotijuba and Mosqueiro, whereas temperature varied from 26.28 °C to 29.55 °C, being highest at Onças. In the dry to wet transition, salinity varied from 0.05 to 0.57, and temperature from 25.95 °C to 29.32 °C, tending to be highest at Mosqueiro. In the wet season, salinity was very low (0.01 to 0.25) and varied little among sites, but was relatively higher (0.25) at Mosqueiro sites. Temperature varied relatively more in the wet season (24.6 °C to 28.6 °C), being highest at Combu and decreasing to Mosqueiro.

Dissolved oxygen (% saturation), in general, showed moderate to high values in the dry and wet

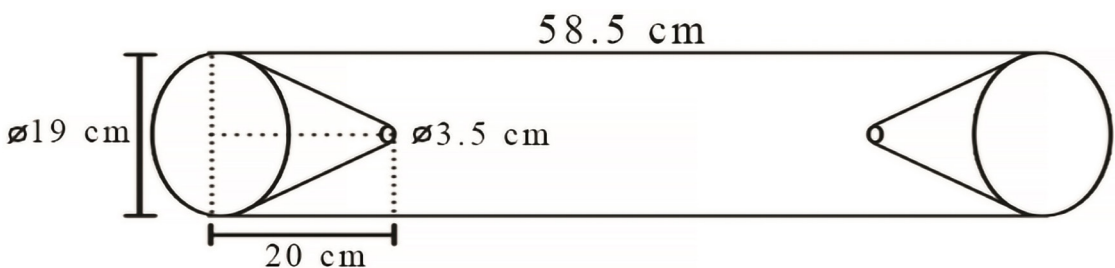


Figure 2. Schematic diagram of an artisanal *matapi* trap for sampling decapod crustaceans between October 2013 and May 2014 in the Guajará Bay and Mosqueiro Island.

seasons, between 50 and 80, however, during the dry to wet transition, some Cotijuba and Mosqueiro measurements had markedly lower values around 10%. In the wet season, values were similar among islands. Values of pH were below 7 at all locations in the wet season, whereas in the dry season and in the dry to wet transition, pH varied more, with highest values of 8.56 and 8.77 occurring in the dry to wet transition (Figure 3). In general, pH tended to be higher at Cotijuba and Mosqueiro, and lower at Combu and Onças.

Differences in environmental variables among islands and seasons were significant, the most

important being seasonal differences, which explained 44.7% of the variation in the data (Table 1). However, interactions among islands, seasons and sites, that is, a lack of consistency in seasonal patterns in environmental variables among islands and the creeks sampled therein, were significant explaining 24.1%, and residual unexplained variability, a further 18.7% (Table 1).

3.2. Biotic data

A total of 8,367 decapod crustaceans were captured, of which 7,371 were *Macrobrachium amazonicum*, the most common shrimp species

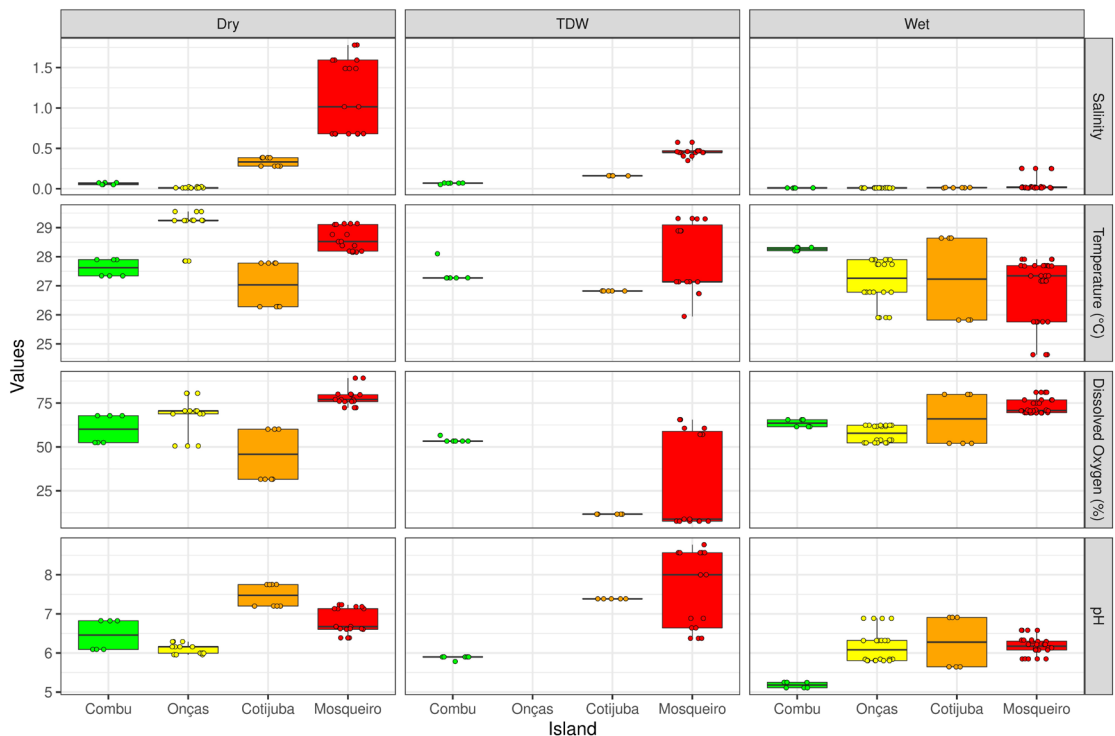


Figure 3. Seasonal variation in salinity, temperature (°C), dissolved oxygen (%) and pH at sites on Combu, Onças, and Cotijuba Islands in Guajar Bay and Mosqueiro Island in the Dry, Transition from Dry to Wet (TDW), and Wet seasons between October 2013 and May 2014.

Table 1. Permutational multivariate analysis of variance (PERMANOVA) summary, testing for differences in decapod occurrence and composition sampled at sites on Combu, Onças, and Cotijuba Islands in Guajar Bay and Mosqueiro Island in the Dry, Transition from Dry to Wet (TDW), and Wet seasons between October 2013 and May 2014.

Source of variation	df	SS	MS	pseudo-F	R ²	P
Island	3	6614	2204.7	24.095	0.125	0.000999
Season	2	23636	11818.2	129.161	0.44671	0.000999
Island:Season	5	6244	1248.8	13.648	0.11801	0.000999
Island:Site	11	6536	594.2	6.494	0.12353	0.000999
Residuals	108	9882	91.5		0.18676	
Total	129	52912			1.00000	

df: degrees of freedom, SS: Sums of Squares and MS: Mean Squares.

(Table 2). Samples also included 36 freshwater crabs (including 30 *Pachygrapsus gracilis*) and two marine crabs, *Callinectes bocourti*. Considering the entire study period, the highest density of individuals (5,144), greatest species richness (10 species) and highest Margalef diversity (1.05) were recorded at Mosqueiro Island. Equitability was highest at Combu (0.28), and Shannon diversity (0.52) was highest at Onças Island.

In the dry season, density was higher in Cotijuba and Mosqueiro and species richness was generally similar among islands, but lower at Mosqueiro (Figure 4). Margalef diversity was similar among islands, being slightly lower at Mosqueiro. Evenness and Shannon diversity were similar among islands, except at Onças where values were lower. In the Transition from Dry to Wet (TDW), density was highest at Cotijuba, albeit a single observation, whereas richness, Margalef, Evenness and Shannon diversity were similar among Combu, Cotijuba and Mosqueiro islands (Figure 4). In the wet season, density increased from Combu to Mosqueiro. Species richness and Margalef diversity were highest at Onças and similar at the other islands. In contrast

to density, Evenness and Shannon diversity decreased from Combu to Mosqueiro in the wet season (Figure 4). In general, ecological indices are similar in the dry and transition dry to wet seasons, and in the wet season, dominance occurs at Mosqueiro Island.

Onças Island appears to be well represented by sampling, reaching a well-defined plateau, as well as Combu and Cotijuba islands, which appear to be close to reaching a plateau. Mosqueiro Island, despite the higher sampling effort, is not close to the plateau, also reflected in the curve involving the total sampling effort at all the islands (Figure 5).

Based on presence and absence data, the decapod fauna in Cotijuba was clearly distinct from that of Combu, whereas those of Mosqueiro and Onças overlapped considerably with the other islands (Figure 6A). Decapod occurrence and composition in the dry season was more distinct from that of the wet season and the dry to wet transition, the latter two overlapping entirely (Figure 6B). *Macrobrachium* sp., *M. amazonicum* and *M. surinamicum* were more associated with the dry season, when temperature, salinity and dissolved

Table 2. Density (upper value) and relative frequency (% , lower value) of each decapod species captured at Combu, Onças, and Cotijuba Islands in Guajará Bay and Mosqueiro Island between October 2013 and May 2014, considering the entire study period.

Species	Island and Season											
	Combu			Onças			Cotijuba			Mosqueiro		
	Dry	TDW	Wet	Dry	TDW	Wet	Dry	TDW	Wet	Dry	TDW	Wet
<i>Callinectes bocourti</i>	-	-	-	-	-	-	-	-	-	-	-	2
												0.08
<i>Macrobrachium acanthurus</i>	-	4	16	-	-	32	-	5	1	-	5	9
		3.54	10.32			5.87		0.66	0.30		0.41	0.36
<i>Macrobrachium amazonicum</i>	258	101	133	429	-	458	432	719	308	1129	1059	2345
	88.36	89.38	85.81	93.06		84.04	76.33	94.98	92.22	80.41	87.67	92.61
<i>Macrobrachium jelskii</i>	-	-	-	3	-	1	1	1	-	1	-	1
				0.65		0.18	0.18	0.13		0.07		0.04
<i>Macrobrachium</i> sp.	27	6	6	20	-	38	132	30	23	272	140	159
	9.25	5.31	3.87	4.34		6.97	23.32	3.96	6.89	19.37	11.59	6.28
<i>Macrobrachium surinamicum</i>	7	-	-	9	-	6	-	-	-	2	-	-
	2.40			1.95		1.10				0.14		
<i>Pachygraulis gracilllis</i>	-	1	-	-	-	7	1	2	2	-	3	14
		0.88				1.28	0.18	0.26	0.60		0.25	0.55
<i>Penaeus monodon</i>	-	-	-	-	-	-	-	-	-	-	-	1
												0.04
<i>Uca mordax</i>	-	1	-	-	-	3	-	-	-	-	1	-
		0.88				0.55					0.08	
<i>Valdivia serrata</i>	-	-	-	-	-	-	-	-	-	-	-	1
												0.04
Total	292	113	155	461	-	545	566	757	334	1404	1208	2532
Total Geral	N = 8367											

TDW: Transition from Dry to Wet.

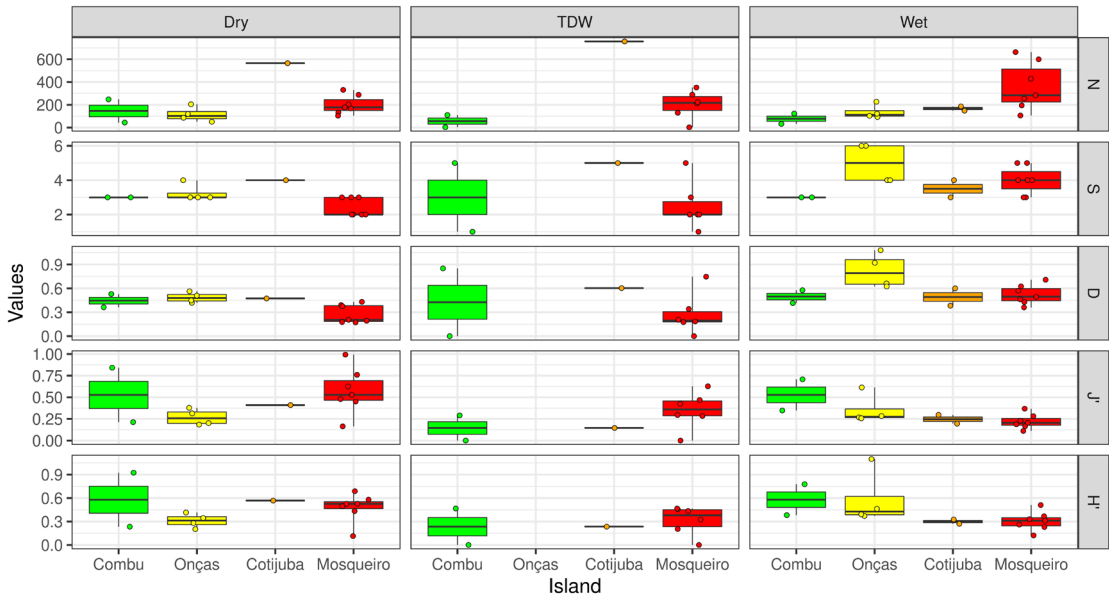


Figure 4. Ecological indices recorded for the decapod fauna at Combu, Onças, Cotijuba islands in Guajará Bay and Mosqueiro Island, in the Dry, Transition from Dry to Wet, and Wet seasons between October 2013 and May 2014. N = density, S = number of species, D = Margalef index, J' = equitability, H' = Shannon index. Data for Onças Island were not available for the Transition from Dry to Wet (TDW). Sample size varied from 1 to 7 (Dry), 0 to 6 (TDW) and 2 to 7 (Wet).

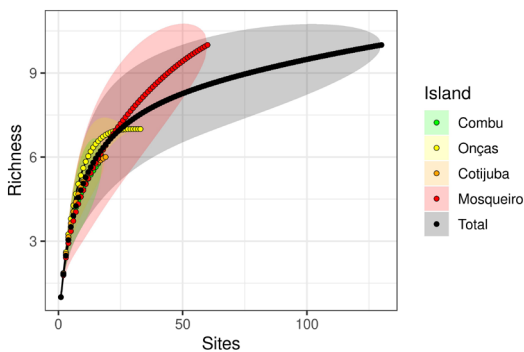


Figure 5. Species accumulation curves (Jackknife 1, random order of sites) for samples of decapods crustaceans in Guajará Bay and Mosqueiro Island between October 2013 and May 2014. Curves for each island and the total sampling effort.

oxygen were higher, especially at Mosqueiro. Other species, especially, *M. acanthurus*, *Pachygraulis gracillis*, *M. jelskii* and others were associated with the wet season and the dry to wet transition, especially at Onças, Cotijuba and Combu islands. Of all the environmental variables, pH appeared to be least associated with the fauna by island or by season (Figure 6B).

The multivariate pattern in faunal occurrence was significantly, though weakly, associated (Envfit R^2 , P) with temperature ($R^2 = 0.064$, $P = 0.012$)

and salinity ($R^2 = 0.056$, $P = 0.034$) but not with dissolved oxygen ($R^2 = 0.037$, $P = 0.098$) and pH ($R^2 < 0.0001$, $P = 0.99$).

4. Discussion

The Guajará bay can be considered as having the environmental characteristics of a river during almost all the year, due to discharge from the large Amazon and Tocantins/Araguaia basin drainages, which effectively inhibit the advance of the oceanic saline wedge, especially during the rainy season. Guajará bay is most influenced by the mass of marine waters entering the mouth of the estuary in the dry season (Cavalcante et al., 2017).

Temperature showed relatively low variation in our data (24.63-29.55 °C). The constant water temperature is typical of the estuaries of the Amazon coast (Carvalho & Couto, 2011) and confirms the thermal stability of equatorial coastal regions. Variation in water temperature among islands did not differ from that of other nearby locations, such as Vigia, 27.5 °C and 28.0 °C in the wet and dry seasons, respectively (Silva et al., 2002a). Unlike temperate regions, where temperature is a seasonally limiting factor for decapod growth and distribution, in tropical regions, relatively constant favorable conditions allow for mating and larval development

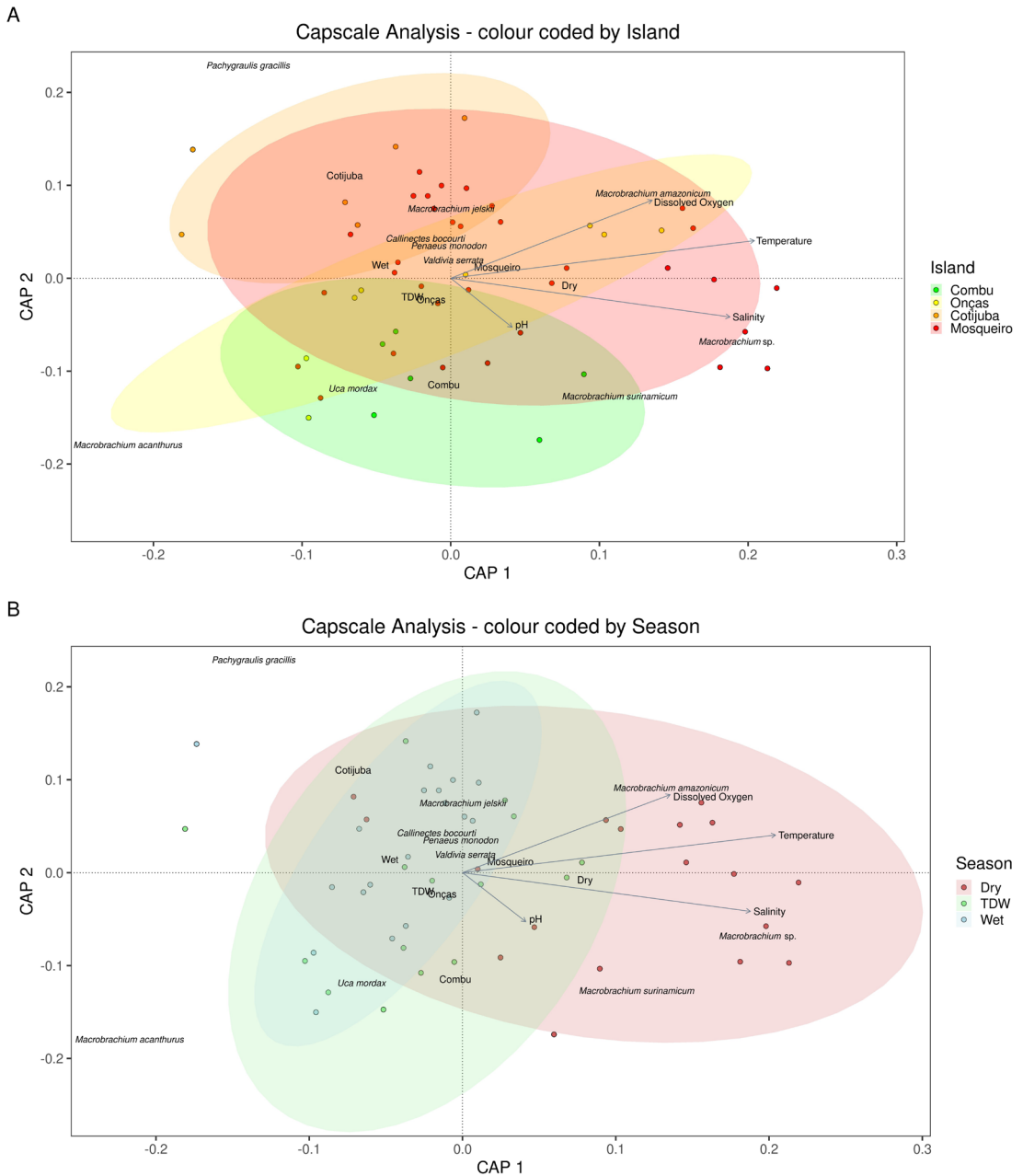


Figure 6. Ordination of the first two axes resulting from the CAP analysis of decapod occurrence and species composition in samples trapped on islands Combu, Onças, Cotijuba islands in Guajar Bay and Mosqueiro Island in the Dry, Transition from Dry to Wet, and Wet seasons between October 2013 and May 2014 in relation to the abiotic variables salinity, temperature (C), dissolved oxygen (% saturation) and pH. The ordination is overlaid with the ellipses of each island (A) and season (B).

throughout the year (Costa & Soares-Gomes, 2009; Brando et al., 2011).

The low variability in salinity (0.01-1.78) differs from that observed by Lima et al. (2019) who recorded salinity from 3 to 35 in the Marapanim, an Amazon estuary further east. However, our results confirm those of Rosrio et al. (2016) in Guajar Bay, which show that this estuary does

not present high salinity along its longitudinal profile, since there is rapid dilution of sea water by river discharge, thereby lowering salinity to between 0 and 5. Although in an estuarine region, our sampling sites were closer to the influence of large rivers, such as the Acar, Guam, and Maguar rivers, and thus our salinity values were low and invariable. Abrupt changes in sea level of up to six

meters during the wet season are common in the region, due to a combination of macrotides and high freshwater discharge, resulting in oligohaline waters that keep the temperature and salinity constant in this estuarine region (Barros et al., 2011).

Intense mixing of waters of differing salinity allows coexistence of both marine and freshwater species according to seasonality (Bentes et al., 2011). The results of the present study re-emphasize the influence of relatively low salinity levels on the distribution of the decapod species found in this region, which, according to Cavalcante et al. (2017), would account for the occurrence of freshwater crab species - *Sylviocarcinus devileii* and *Sylviocarcinus pictus*, especially at Belém and Combu Island - where salinity was virtually zero throughout the year - as well as the presence of the marine-estuarine genera *Uca* and *Callinectes* on Mosqueiro Island. The wet season pH was slightly more acidic, as rainwater has a pH of around 5.5, and the influence of rainwater runoff may decrease pH. Variation in pH is the result of the interaction of several biogeochemical factors and is a primary indicator of water quality (Blume et al., 2010), however, regardless of the seasonal period, our values were close to those found by Montes et al. (2009) also in Guajará Bay, with a minimum of 5.10 and a maximum of 6.08, showing that anthropogenic factors did not appear associated with changes in pH in this period.

Relatively successful catches of species of the *Macrobrachium* genus seem to be a characteristic of Amazon estuary. However, the species *M. amazonicum* presented a higher density than the other species of the same genus, this difference may be related to the ecological flexibility of this species (Bentes et al., 2014). High densities of *M. amazonicum* were recorded at all sites, reflecting the tolerance of the species to environmental variation, which occurs worldwide in tropical and subtropical fresh and brackish waters, inhabiting a variety of ecosystems (Pileggi & Mantelatto, 2010; Vergamini et al., 2011) from continental to coastal environments with different salinity gradients; (Short, 2004; Freire et al., 2017).

The presence of the exotic species *Penaeus monodon* in the Brazilian Amazon has been previously reported. Silva et al. (2002b) registered the presence of two specimens from the continental shelf of the State of Amapá. Cintra et al. (2011) reported the capture of an individual by an industrial fishing vessel operating on the continental shelf of the State of Pará and Cintra et al. (2014)

recorded the capture of three more individuals in 2013 also by an industrial fishing vessel operating on the Amazon continental shelf in the State of Pará. The species *P. monodon*, which may have been introduced into Brazilian waters by ballast water from ships (Farrapeira et al., 2007), may be a threat to local Amazonian species, as the region seems to represent an ideal environment for their survival (Cintra et al., 2014, Lutz et al., 2015). The introduction of exotic species into different ecosystems may affect the survival of native species (Rodríguez, 2001), which may lead to competition for resources, especially food, between species, generate changes in the balance of predator-prey relationships, and significantly impact trophic webs (Snyder & Evans, 2006; Baum & Worm, 2009; Lord et al., 2019).

The type of trap used in the present study may account for the reduced proportion of crabs (marine and freshwater) in the samples, although this had been expected, given that local coastal communities traditionally use these traps for the harvesting of shrimp (Odinetz-Collart & Moreira, 1993). At higher salinities – closer to the sea – density and the number of species increased. Mosqueiro Island is closest to the sea and is located within an area of intense mixing of saline and fresh waters, resulting in a nutrient-rich environment (Smith, 2002), which may favor the density of decapods.

The CAP analysis identified an association between *M. acanthurus* and the wet season, which is consistent with Díaz Herrera et al. (1998), who recorded the tolerance of the species for freshwater or low salinity, with adults capable of osmoregulation in fresh and brackish water at temperatures above 15 °C. However, during the larval stage, *M. acanthurus* has low tolerance to salinity (Choudhury, 1971).

The composition of the decapod fauna in the present study was variable and related to both location and season. The resulting temporal and spatial mosaic of salinity favors, besides shrimps, other crustaceans such as crabs. *M. jelskii* is classified as a species restricted to freshwater (Melo, 2003), as evidenced by a greater association with the inner estuary in Onças and Combu islands that receive a greater riverine inflow and less influence from saline coastal waters. In addition, *M. jelskii* has abbreviated larval development (Magalhães, 2000), where females carry only a few large eggs (Anger, 2013). Palaemonidae species with abbreviated larval development occupy strictly freshwater habitats (Rabalais & Gore, 1985).

The relative abundance of *M. amazonicum* during the dry season reflects the population dynamics of this species, which tends to be rare during the wet season (Bentes et al., 2011). The increased volume of water during the wet season may facilitate the dispersal of many species of crustacean and fish (Odinetz-Collart & Moreira, 1993). Densities may thus be higher during the dry season, when river volume decreases and many individuals move out of the floodplain lakes, facilitating trapping. Variation in shrimp catches in the Amazon depends on the intensity of the floods, which interfere with survival and growth. In Amazon basin floodplain lakes, catches are higher during the dry season and lower during the wet season, due to the wide spatial dispersion of individuals with higher water volume and flow (Odinetz-Collart & Moreira, 1993). Although *M. surinamicum* is more associated with the dry period in our CAP analysis, Cavalcante et al. (2017) found that its distribution was not influenced by either salinity or temperature in the Guajar estuary, possibly since these factors did not change very much in the region, also evidenced in our results (salinity 0.01-1.78, temperature 24.63-29.55 °C).

Macrophyte wet season growth reduces shrimp intra-species competition, through increased microhabitat availability in the early stages of life (Nurminen et al., 2007) and introduction of suspended material increases productivity and energy flow (Paiva et al., 2006). Tides are the major natural disturbance in mangrove areas along the Par coast, directly affecting abundance of zooplankton, crustaceans, and fish, as well as promoting the entry and exit of wastes and nutrients (Dittmar & Lara, 2001; Schories et al., 2003; Krumme et al., 2004; Krumme & Liang, 2004).

The highest shrimp density was observed on Mosqueiro Island, which is the largest and most populous island studied in present work (IBGE, 2010). Thus, a larger human population may be related to higher amounts of suspended organic matter that is a food source for shrimp. Eutrophication processes due to phosphorous and nitrogen-rich compounds from domestic and industrial waste cannot be recognized as a positive scenario (Viana et al., 2010), and causes long term deleterious effects in the benthic fauna (Dorgham, 2014). Eutrophication of aquatic environments via sewage generates poor water quality, represented by a higher biochemical oxygen demand and consequently low dissolved oxygen concentrations due to the proliferation of microorganisms.

Miranda et al. (2016) observed values above the allowed (5mg/L) by CONAMA (Conselho Nacional do Meio Ambiente) Resolution No. 357/2005 (Brasil, 2005) for biochemical oxygen demand and low values of dissolved oxygen on Mosqueiro Island, relating the disposal of urban effluents and vessels such as pollution sources. However, our values of dissolved oxygen were similar between the islands, especially during the wet and dry seasons, which does not seem to be a limiting factor for both species diversity and abundance.

Studies of density and diversity of species between areas that receive different levels of environmental impacts are of vital importance for understanding how biotic and abiotic dynamics react to these factors of pollution of estuarine and coastal waters. Basic physical-chemical parameters and ecological indices can be especially valuable for the understanding of the current status of an ecological community, as well as future impacts (Mason, 1991). While ecological indices are often criticized due to their limitations for understanding community dynamics, they can provide a useful comparative tool for the analysis of impacts on community structure (Morris et al., 2014), especially in the long-term, given that impacts on species diversity may often be extremely subtle or masked by the dynamic restructuring of the community (Kay et al., 2018).

Aquatic organisms may be exposed to multiple stressors, such as the discharge of pollutants into the water, overfishing, habitat modifications and so on (Scholz et al., 2012; Ward et al., 2013; Hook et al., 2014). Due to their short life cycle, presence of a larval phase, and their importance as components in trophic webs, crustaceans are often used as bioindicators by water quality monitoring programs (Ghisi et al., 2017; Kumar et al., 2017). The islands in Guajar Bay and Mosqueiro Island are heterogeneous environments, with shipping and ports, domestic and industrial effluents, and fishing and aquaculture operations affecting primarily its eastern margin (Mosqueiro Island and the islands around Belm). Our results show that although this region suffers from greater anthropogenic disturbances, mainly because it has a large human population, the current diversity and density of shrimp and crabs appear not to be greatly affected. However, the current species diversity found within the study area may change significantly over time, leading to ecological imbalances, which may ultimately affect the area's traditional artisanal fisheries.

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